The Large and Yeager (2004) dataset for Common Ocean Reference Experiments

Stephen M. Griffies and Michael Winton and Bonnie L. Samuels
NOAA Geophysical Fluid Dynamics Laboratory
PO Box 308, Forrestal Campus
Princeton, New Jersey, 08542 USA

(Manuscript last edited 16 August 2004)

ABSTRACT

These notes describe the Large and Yeager (2004) dataset supported at GFDL, as well as other related files given on the website. Corrections were applied to their dataset as per the Large and Yeager (2004) report. This dataset is being provided for use with the Clivar Working Group for Ocean Model Development's (WGOMD) Common Ocean Reference Experiments (CORE). We also provide comments on running coupled ocean-sea ice models using this dataset to force the models.

1 Introduction

Large and Yeager (2004) provide algorithms for correcting atmospheric data products to facilitate the integration of ocean and sea ice models. Their algorithms have been implemented at GFDL to produce both a Corrected Normal Year Forcing (CNYF) and Corrected Internanual Forcing (CIAF). The purpose of this document is to provide some notes on these corrected forcing fields, and comments on how we use this data at GFDL to run coupled ocean sea ice models. This document and the web page have been developed by GFDL scientists in support of the Clivar Working Group for Ocean Model Development (WGOMD) Common Ocean Reference Experiments (CORE). Details of the CORE protocol are presently being documented and will be described elsewhere.

2 Contents of the web page

This web page contains the following datasets.

- Uncorrected Normal Year Forcing (unCNYF) fields
- Uncorrected Internanual Forcing (unCIAF) fields
- Corrected Normal Year Forcing (CNYF) fields, version 1.0.
- Corrected Interannual Forcing (CIAF) fields, version 1.0.

Each of the above datasets contain the following fields on a horizontal grid of 192 longitude points and 94 latitude points

- monthly varying precipitation (12 time steps)
- daily varying shortwave and longwave (365 time steps–no diurnal cycle and no leap years),
- six-hourly varying 10m temperature, humidity, zonal velocity, meridional velocity, and sea level pressure ($4 \times 365 \times 43$ time steps–no leap years for the interannual data).

Besides the present set of notes, these web pages also contain the following files.

- The Large and Yeager (2004) technical report provided by NCAR. This report details both the uncorrected and corrected data sets used to produce the forcing fields. Note that some have had problems downloading this file. Please contact Stephen Yeager at yeager@ucar.edu if you need help.

- Fortran code `advance.f90` provided by NCAR which corrects the raw data.
- Ferret code `make_data.csh` provided by GFDL which implements the algorithms from `advance.f90` in a Ferret script.
- Fortran code `ncar_ocean_fluxes.f90` provided by GFDL which computes the NCAR bulk formulae recommended for use in CORE.
- Sea surface salinity restoring file `PHC2_salx.nc` provided by NCAR for use in computing a restoring salt or fresh water flux with CORE.

We provide both the uncorrected and corrected forcing fields for two reasons. (1) The user may wish to run simulations as at NCAR whereby corrections are applied to the uncorrected fields at runtime by using `advance.f90`. This procedure facilitates further refinement to the corrections without needing to generate a new "corrected" dataset. (2) At GFDL, we perform the corrections prior to runtime using the above Ferret script. Others may wish to do so as well.

3 Reasons for using this dataset

The release of the Large and Yeager (2004) provides the global ocean climate modeling community with an important advance in our ability to integrate ocean-ice models without a fully coupled atmospheric GCM. This advance builds in many ways on an earlier effort by Röske (2001) for a Pilot-Ocean Model Intercomparison Project (POMIP). There are other similar datasets that can be used. However, we prefer the Large and Yeager (2004) data for the following reasons.

- The data, which combines reanalysis with satellite data, has advantages over that based solely on reanalysis (Röske, 2001, was based soley on ECMWF). Advantages are discussed in Large and Yeager (2004).
- Both normal year *and* interannual data are provided.
- The datasets are documented and supported by NCAR, with assistance from GFDL for releasing the corrected versions. Future releases of this data can be expected as advances are made to the data products and our understanding of their biases.

4 Comments on the data and experimental protocols

The CORE protocol will be documented within the next few months. In the meantime, here are some details for how the ocean-ice models are run at GFDL using the corrected normal year forcing (CNYF1p0). Note that experience with the interannual varying data at GFDL is minimal, as this data has only recently been developed.

- The interannual forcing fields in CIAF1p0 do not contain leap-years. That is, each year has the same length of 365 days. This limitation may introduce some difficulties for those using the data for reanalysis efforts.
- There is generally no restoring to surface temperature. Instead, turbulent heat fluxes are derived from the NCAR bulk formulae using the model SST and the 10m atmospheric fields. The radiative heating is provided from the shortwave and longwave datasets. We originally tried to use the GFDL bulk formulae in our experiments. However, the fluxes produced from the two bulk formulae are quite distinct when running with observed SSTs. In particular, the wind stresses were larger with the GFDL formulation (which follows ECMWF) and the latent heat fluxes were larger with the NCAR formulation. The differences were traced to differences in the neutral transfer coefficients (roughness lengths). As the forcing datasets were tuned using the NCAR bulk formulae, we recommend using the same bulk formulae for CORE experiments.
- Models should use properly referenced meteorological data consistent with what the bulk for-

mulae expect. Reanalysis meteorological data is commonly distributed at 2m while oceanic turbulent transfer schemes often require 10m data. For accuracy, it is essential that the data be re-referenced to 10m. The re-referencing algorithm and the flux calculation algorithm are closely related. So, ideally, one should re-reference using a scheme that is compatible with the flux scheme.

- Models should use the same treatment of saltwater vapor pressure. The vapor pressure over seawater is about 2% less than that over fresh water. This difference is not negligible compared to the 20% subsaturation of marine air that drives evaporation. Consequently, the effect should be included in all models participating in a comparison.

- It is desirable to use high frequency meteorological data. A one month run of an AMIP model was used to explore the flux errors associated with averaged meteorological inputs. With daily winds, temperatures, and humidities, latent heat fluxes are underestimated broadly over the winter storm track band by some 10's of W/m2. There was also a smaller underestimate located in the summer storm track band. Experiments that refined the temporal resolution of the flux inputs individually showed that high frequency winds are most important for reducing the error but temperature and humidity frequency also contribute. When all inputs are given at 6 hourly frequency, the global RMS error is about 1 W/m2 versus near 8 W/m2 for daily inputs.

- The river runoff data has only a single time step as it represents annual mean runoff. This data has been spread out from the river mouths in a manner used by NCAR for their climate models. This approach is thought to account for some unresolved mixing that occurs at river mouths in Nature. We provide a remapping scheme which will take the river data and map onto a new grid, so long as the new grid is logically rectangular (such as the GFDL tripolar grid). GFDL can provide some assistance with this remapping if you have problems.

- An issue for comparisons is the strength of the salinity restoring. Although relatively strong salinity restoring will reduce drift, it has no physical basis and so it is desirable to use the weakest possible restoring. A weak restoring also has the benefit of allowing increased variability in the surface salinity and deep circulation. However, when the salinity restoring and effective temperature restoring timescales are very different, the experiment becomes analogous to a mixed boundary condition experiment. The ability of mixed boundary conditions to represent the adjustment of the ocean in the coupled system has been called into question. In particular, mixed boundary condition experiments with strong temperature restoring have been shown to be excessively susceptible to the polar halocline catastrophe, in which a fresh cap develops in high latitudes and shuts down overturning (Zhang et al, 1993).

  The effective temperature restoring determined by numerically linearizing the CORE thermal boundary condition is quite strong, yielding piston velocities around 1-2 m/day. The salinity restoring strength chosen for a comparison between NCAR and GFDL simulations with the normal year forcing was two orders of magnitude smaller than this. Under these boundary conditions the GFDL model Atlantic overturning collapsed in 50 years and remained collapsed at 100 years. Contributing to the collapse was an effect not present in traditional mixed-boundary condition experiments: as the overturning weakened, the North Atlantic sinking regions cooled leading to a reduction in evaporation of about 0.1 Sv. The GFDL ocean-ice model collapse was in contrast to the behavior of the same ice and ocean components in the GFDL climate model runs with an interactive atmospheric model. Here, the overturning is stably maintained in multi-century runs at about 15-20Sv. To explore the possible role of ice dynamics in the collapse, a companion run with immobile sea ice was conducted. The overturning in this experiment also collapsed. The NCAR model overturning, while weaker than that in the NCAR climate model, remains at about 10 Sv until the end of the 100 year experiment, and slightly increases slightly upon running longer.

Here is a summary of some points to keep in mind regarding salinity forcing.

1. At GFDL, we use a real water flux instead of a salt flux. Hence, the salinity restoring is converted to a water flux.
2. To ensure that there is no accumulation of salt in the model arising from the salinity restoring, we remove the globally integrated salt content from the restoring field. We do this global procedure at each model time step. Note that in fact, as the GFDL ocean model uses real water fluxes, this normalization occurs on the precipitation minus evaporation implied by the salinity restoring.
3. As the ocean SST will deviate from that used to balance the dataset's water content, there is no guarantee that the water will balance as the model integrates. Hence, in addition to removing the global mean salt/water associated with the restoring, we remove the global mean evaportation minus precipitation minus river runnof that results from the bulk formulae. Again, this normalization ensures that no water accumulates in the model.
4. At NCAR, the salinity restoring is 4 years over 50m, which is a very weak piston velocity. Runs at GFDL using MOM4 with this weak restoring result in a meridional overturning that collapses within a few decades. Multiple simulations with one degree and two degree classes of global models have been run, where differences are due to changes in model physics. Nothing was found to stablize the overturning. Additionally, use of the same weak salinity restoring with the POMIP dataset of Röske (2001) results in similar overturning collapse. This unstable behavior is a puzzle since the NCAR model (which uses POP, which is another z-model) remains stable with the weak restoring. Other model differences are being investigated to see if a "smoking gun" can be found.

   Our analysis indicates that the MOM4 ocean-ice simulations are on the unstable side of a mixed boundary condition bifurcation. Hence, for purposes of studying ocean climate under a stable regime with a nontrivial overturning, we have resorted to stronger salinity restoring. We are very interested to know of other model behaviors.

   It is noteworthy that the same ocean-ice configuration which results in an unstable overturning with the NCAR forcing is presently being run in two GFDL coupled climate models. The key difference in the coupled models is the atmospheric dynamical core, with one using a B-grid and the other a C-grid finite volume. In both coupled models, the ocean meridional overturning remains robust (15Sv-20Sv) for hundreds of years. So the behavior in the ocean-ice experiments with the NCAR data remain consistent with a mixed boundary condition instability.

References

Large, W., and S. Yeager, 2004. Diurnal to decadal global forcing for ocean and sea-ice models: the data sets and flux climatologies. NCAR Technical Note: NCAR/TN-460+STR. CGD Division of the National Center for Atmospheric Research.

Röske, F., 2001. An atlas of surface fluxes based on the ecmwf reanalysis a climatological dataset to force global ocean general circulation models. Report No. 323. Max-Planck-Institut für Meteorologie.